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THE WEATHER BUREAU

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FIGURE 1.—Central office of the United States Weather Bureau, Washington, D. C.

Description of Illustrations

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FIGURE 1. CENTRAL OFFICE OF WEATHER BUREAU 11

Showing main building at Twenty-fourth and M Streets NW., Washington, D. C. Here are located the administrative offices; the principal forecasting officials and facilities for the United States; the shops and laboratories where all instruments are tested, and many made complete for use by the bureau stations; one of the best meteorological libraries in the world; and the various divisions whose operations cover all the stations of the service.

2. COOPERATIVE WEATHER OBSERVERS' EQUIPMENT 9

Maximum and minimum thermometers exposed in thermometer shelters, and rain gages for collecting rain and snow; these are observed daily by more than 4,000 public-spirited persons for the benefit of their communities.

3. THERMOGRAPH 13

Writes the temperature continuously, on clock time.

4. RAIN GAGE 14

Tipping bucket; makes an automatic record of every hundredth of an inch of rainfall, indicating the time of beginning and ending and the rate of fall for every shower or storm.

5. PILOT BALLOON AND THEODOLITE 15

Rubber balloons, 6 inches in diameter when uninflated, are filled with hydrogen to a diameter of about 28 inches and released. They rise at a nearly constant rate of about 180 meters, or 600 feet, per minute. Their movements are watched through a theodolite, and the azimuth and elevation angles are recorded once each minute and telephoned to a computer. (See fig. 6.)

6. PILOT-BALLOON PLOTTING BOARD 16

The angular readings referred to under Figure 5 are entered on a suitable record form, and the horizontal distances of the balloon from the observation point are computed for each minute by means of a slide rule. These distances are indicated on the plotting board, the proper directions being determined from the azimuth readings. The wind directions and velocities are then taken off by means of suitable scales for various heights.

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FIGURE 7. SOUNDING BALLOON AND METEOROGRAPH 17

Rubber balloons, 3 to 5 feet in diameter, and filled with hydrogen, carry a meteorograph, designed by S. P. Fergusson, to heights of 10 to 15 miles, with a record of 20 miles thus far. The meteorograph automatically records the pressure, temperature, and humidity at all heights reached.

8. AEROMETEOROGRAPH MOUNTED ON AN AIRPLANE 18

This instrument also records pressure, temperature, and humidity at all heights reached.

9. KITE METEOROGRAPH 19

Designed by C. F. Marvin. Records pressure, temperature, humidity, and wind velocity at all heights reached.

10. CAPTIVE BALLOON, PLATFORM, AND REEL 31

Used during very light winds. The balloon carries a meteorograph which records pressure, temperature, and humidity. As soon as the greatest possible height is reached the balloon is brought back to earth by means of a reel and the fine piano wire to which it is attached.

11. A WEATHER BUREAU OBSERVATORY 34

The United States Weather Bureau

As an institution the Weather Bureau exhibits the growth and development of meteorology and its practical application through the medium of the electric telegraph, radio, and other forms of communication, in the performance of a systematic and continuous service to the public and in the interest of agriculture, commerce, and navigation. The invention of the barometer, thermometer, hygrometer, and other meteorological instruments enabled accurate observations of atmospheric phenomena to be made, from the study of which some of the laws that govern the changes therein have been deduced. The importance of a foreknowledge of weather changes in the conduct of the daily affairs of life was early recognized. The invention of the telegraph made the dissemination of this information possible, and practical meteorologists soon began to formulate plans for the preparation and effective distribution of weather forecasts and warnings. These efforts led to the organization of weather bureaus, some of them antedating our own. in nearly every civilized country.

Historical

The Weather Bureau of the United States has reached its present development mainly under three organic laws. The first was a joint resolution approved February 9, 1870, which is as follows:

Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of War be, and he hereby is, authorized and required to provide for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories of the United States, and for giving notice on the northern lakes and on the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms.

In compliance with the appropriation bill of 1871, reports relative to the stages of water in the rivers were added to the above. The appropriation bill approved June 10, 1872, provided:

For expenses of storm signals announcing the probable approach and force of storms throughout the United States, for the benefit of commerce and agriculture; and that the Secretary of War be, and hereby is, authorized and required to provide, in the system of observations

and reports in charge of the chief signal officer for such stations, reports, and signals as may be found necessary for the benefit of agriculture and commercial interests.

In the act of Congress transferring the meteorological work of the Signal Office to the Weather Bureau of the Department of Agriculture, approved October 1, 1890, the duties of the service are thus summarized:

The Chief of the Weather Bureau, under the direction of the Secretary of Agriculture, shall have charge of forecasting the weather; the issue of storm warnings; the display of weather and flood signals for the benefit of agriculture, commerce, and navigation; the gaging and reporting of rivers; the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation; the reporting of temperature and rainfall conditions for the cotton interests; the display of frost, cold wave, and other signals; the distribution of meteorological information in the interest of agriculture and commerce; and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, as are essential for the proper execution of the foregoing duties.

The laws are but the crystallized expression of the outcome of years of experience on the part of those interested in meteorology. Thus, the laws of 1871 and 1872 mark the end of a long agitation, the purpose of which was to persuade Congress that forecasts of the weather were practicable in the United States and that an organized systematic effort to give the public due warning of the approach of storms was worth a trial. The organization of this service was intrusted to the Signal Service of the War Department. At first the service was for the benefit of navigation on the seacoast and on the Great Lakes, but it was soon extended to include the interior districts and the great rivers of the central valley.

The benefits of the weather service were soon recognized by business industries and the general public. Although started primarily in the interest of navigation it became necessary to enlarge the scope of service to include agriculture and commerce and to extend the field of meteorological work and investigations. This enlargement of the original purposes and the important place it had earned in the business and civil life of the Nation led to the conclusion that as a scientific bureau it could function better under civilian than under military control. Accordingly, the second epoch came to an end on July 1, 1891, when the Signal Service of the War Department was relieved of its meteorological duties, and the Weather Bureau of the Department of Agriculture was organized and charged with the future of meteorology in the United States.

Observations and Forecasts

To the general public the Weather Bureau is probably best known through the medium of its daily forecasts and weather maps. These forecasts are based upon simultaneous observations of local weather conditions taken daily at 8 a. m. and 8 p. m., seventy-fifth meridian time, at about 300 regular observing stations in the United States, Canada, Alaska, and the West Indies, supplemented by reports from other countries and from ships at sea. Each Weather Bureau station is operated by one or more trained observers and is equipped with mercurial barometers, thermometers, wind vanes, rain and snow gages, and anemometers, and many of them are equipped with sunshine recorders, barographs, thermographs, and other devices which make a continuous automatic record of the local weather conditions and changes. The results of the twice-daily observations are immediately telegraphed to the central office at Washington, D. C., and other forecast centers, where they are charted for study and interpretation by experts trained to forecast the weather conditions that may be expected to prevail during the following 36 to 48 hours. A complete telegraphic report includes the following data: Temperature, pressure (reduced to sea level), precipitation, direction of wind, state of weather, current wind velocity, clouds, and maximum or minimum temperature since last observation. From these data the forecaster, by comparison with preceding reports, is able to trace the paths of storm areas and forecast their subsequent courses and the attendant weather conditions.

The system for the collection and distribution of telegraphic reports of observations is so arranged that the principal stations in the United States receive reports from a sufficient number of other stations to represent the general weather conditions over a considerable portion of the country.

A careful comparison of the forecasts with the weather for the periods covered show a verification of between 85 and 90 per cent.

Weather services similar to that of the United States are maintained by the Canadian and Mexican Governments, and by a system of interchange daily reports are received from a number of stations in those countries. Daily observations are also received from the Azores, Iceland, Greenland, the Faroe Islands, Great Britain, nearly all the

countries of Europe, China, Japan, the Philippines, Hawaii, and Alaska, and from ships at sea, so that the field represented by the daily reports extends over practically the entire Northern Hemisphere.

Forecast centers are located at Washington, D. C.; Chicago, Ill.; New Orleans, La.; Denver, Colo.; and San Francisco, Calif., at which both morning and evening forecasts are prepared, and centers for limited and special service at Juneau, Alaska, and San Juan, P. R. The States comprised within the five principal forecasting districts are as follows:

Washington, D. C.

Maine.
New Hampshire.
Vermont.
Massachusetts.
Rhode Island.
Connecticut.
New York.
Pennsylvania.
New Jersey.
Delaware.
Maryland.
District of Columbia.
Virginia.
North Carolina.
South Carolina.
Georgia.
Florida (except extreme northwest portion).
Tennessee.
Kentucky.
West Virginia.
Ohio.

Chicago, Ill.

Illinois.
Indiana.
Michigan.
Wisconsin.
Missouri.
Iowa.
Minnesota.
North Dakota.
South Dakota.
Nebraska.
Kansas.

New Orleans, La.

Alabama.
Mississippi.
Florida (extreme northwest).
Louisiana.
Arkansas.
Oklahoma.
Texas.

Denver, Colo.

Montana.
Wyoming.
Colorado.
Utah.
Arizona.
New Mexico.

San Francisco, Calif.

California.
Nevada.
Idaho.
Oregon.
Washington.

Distribution of Forecasts

Within two hours after the morning observations have been taken the forecasts are telegraphed from the forecast centers to nearly 2,000 principal distributing points, whence they are further disseminated by telegraph, telephone, radio, and mail. The forecasts reach nearly 90,000 addresses daily by mail, the greater part being delivered early in the day and none later, as a rule, than 6 p. m. of the day of issue and are available to millions of telephone subscribers within an hour of the time of issue. The rural free mail-delivery system and rural telephone lines are also utilized to bring within the benefits of this system a large number of farming communities.

This system of forecast distribution is wholly under the supervision and mainly at the expense of the Government, and is in addition to, and distinct from, the distribution effected through the press associations and practically every daily newspaper published in the United States.

Weather Maps and Bulletins

The weather maps are mailed immediately after the morning forecast is telegraphed. On these maps the salient features of current weather conditions, temperature, and air-pressure distribution throughout the country are graphically presented. The maps also contain the numerical values of temperature, precipitation, etc., from the observing stations, and in addition a small amount of text describing concisely the main features presented by the map. In order that all sections of the country may receive weather data, maps containing the data in tabular form are issued from about 45 of the larger stations. The maps issued at Washington and other forecast centers contain detailed forecasts for the respective forecast districts, while other station maps and bulletins contain forecasts only for the States and localities in which they are distributed.

The bulletins contain practically the same data and information as the weather maps without graphic presentation on charts. These bulletins are issued at about 90 stations.

In addition to the maps before described, a small weather map is printed in the newspapers of a few cities from a cast made by the Weather Bureau at its nearest local office. Inasmuch as the map is necessarily of diminutive propor-

tions, and since the newspaper publishing it can not find it practicable, as a rule, to give up the space to publish the numerical values on which the map is based, the bureau does not encourage the issue of newspaper weather maps.

Marine Meteorological Service

The present ocean meteorological work of the bureau is the outgrowth of one of the early efforts of the United States to collect and study meteorological data. The plan was conceived and inaugurated about 1850 by Lieut. Matthew Fontaine Maury, an officer in the United States Navy, who was successful in enlisting the cooperation of vessel masters in the world's merchant marine. Within a few years Maury had collected a sufficient number of observations to enable him to construct wind and current charts of the oceans. These had the effect of revolutionizing the ocean-carrying trade by shortening voyages and effecting tremendous savings. Maury's work brought him international fame and honors.

The service is conducted now, as in the beginning, upon a purely voluntary and cooperative basis. The Weather Bureau supplies only blank forms, printed instructions, and such other material as is essential to the making and recording of observations. In the course of a year reports are received from about 1,300 different vessels, representing every maritime nation and reaching every quarter of the globe. The results of their work are returned to seamen in the form of various publications and reports. Chief of these are the pilot charts issued by the Hydrographic Office of the Navy Department, with which the Weather Bureau maintains a close and effective cooperation.

The data collected are used in various ways. New normals or averages are computed from time to time. The development and movement of storms at sea are studied. Information regarding weather conditions at sea is furnished for use of admiralty cases. Observations are used in connection with land data for the construction of weather maps of the world areas.

It is a well-known fact that the oceans act as equalizers of land climates, especially on islands and lands freely open to prevailing winds from the sea, preventing extremes of heat and cold. Since climate is the average of all weather it is obvious that the oceans must also influence the weather of the continents. The study of ocean temperatures is therefore one of the important lines of work of the bureau.

Vessel Reporting

Another service to shipping performed by the Weather Bureau is the reporting of vessels passing in and out of harbors on the Atlantic, Gulf, and Pacific coasts to the owners, agents, and maritime associations. This work is carried on only where the conditions are not such as to warrant commercial interests taking charge of it.

Weather Information by Radio

Marconi began his investigations in wireless telegraphy in 1895, and in March, 1899, he succeeded in transmitting messages by this means across the English Channel from Dover to Boulogne. The Weather Bureau was interested immediately in these investigations because wireless communication presented a field of opportunity to meteorology in the obtaining of current weather information from places inaccessible by telegraph, telephone, or cable, in the transmission of forecasts and warnings to such places, and, further, because it offered a prospect of supplementing or replacing at less cost its extensive system of collecting weather reports by telegraph circuits. Therefore, a few months after Marconi had demonstrated the practicability of wireless communication, the Weather Bureau formulated plans for investigation looking toward the development of apparatus and extension of knowledge of the underlying principles of the science.

Radio is now indispensable to the functioning of weather services and in some countries it has almost supplanted telephone, telegraph, and cable lines in the collecting and distributing phases of their work. In the United States, however, telegraph and telephone are mainly depended on in the collecting of observations from the continental area, while radio is utilized in securing observations from outlying regions, foreign countries, and from ships at sea, and in the disseminating of forcasts, warnings, and information. At the present time weather reports are obtained daily by this means from China, Japan, the Philippines, islands in the Pacific, Alaska, the West Indies, the Azores, England, Iceland, Greenland, nearly all of the countries in continental Europe, and stations in northern Africa and western Asia. During the year 1930, approximately 50,000 radio weather reports were obtained from ships at sea.

Bulletins containing forecasts, warnings, and weather information of interest to mariners are broadcast daily, and

in some instances twice daily by radiotelegraph from 30 stations operated by the Navy Department for the benefit of ships at sea.

At the time of the transfer of the Weather Bureau to the Department of Agriculture in 1891, the potential value of the meteorological service to farmers and agricultural interests generally was clearly recognized, and much was being done for them at that time; but, on account of difficulties inherent in reaching farmers with weather forecasts and warnings in time to be helpful to them, the benefits derived by commerce and navigation far transcended those available to agriculture. The establishing of rural mail service helped, but until recent years the most direct and successful means of furnishing timely weather information has been through rural telephone systems.

Radio has in turn reached a stage of development in which it probably has outstripped all other means of communicating weather information to farmers. Every opportunity is being taken to use it for that purpose, and developments since January, 1921, when the first regular radiophone broadcasts were begun, have been rapid. There are now about 300 broadcasting stations cooperating with the Weather Bureau, and all parts of the United States are within their ranges. The daily weather forecasts are broadcast from each of these on announced schedules at least once daily, and several times a day in many cases. Warnings of cold waves, frosts, floods, heavy snows, etc., are included whenever they are issued. Every agricultural community, however remote it may be from ordinary communication facilities is now on equal terms with populous centers in obtaining weather forecasts and warnings in this way.

Mountain Snowfall Measurements

More than 100 stations are maintained in the mountain regions of Washington, Oregon, California, Idaho, Utah, Montana, Wyoming, Colorado, New Mexico, and Arizona for the purpose of obtaining precise measurements of the depth and water content of the winter snows. These measurements are utilized in forecasting approximately the amount of water that will be available during the succeeding season for the benefit of irrigation, hydroelectric plants, and towns and cities. The Weather Bureau work is augmented by detailed surveys made by

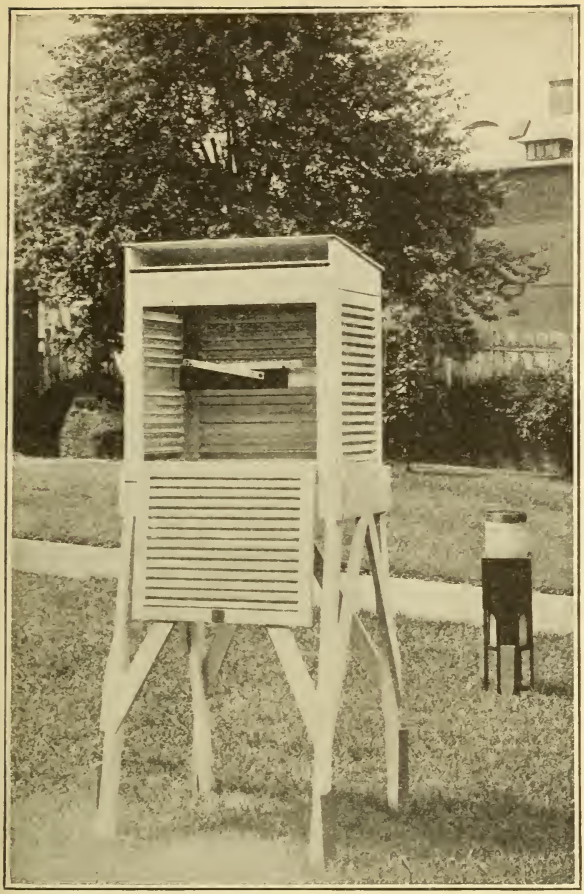

FIGURE 2.—Cooperative weather observers' equipment

water users in the basins from which they draw their supply, and the combined information furnishes a basis for an intelligent and economic use of the snow water, which is essential to the life of a large part of the western Mountain States.

Snow in the eastern mountains does not lie in fields till late in the season, and there is a tendency to consider it less important than in the West. However, it furnishes a large part of the ground water that feeds streams through periods of dry weather, and it is of great economic value. This is being realized, and snow measurements are being gradually extended to the mountains east of the Mississippi River.

Climatological Service

Although the 200 regular observing stations, each representing about 15,000 square miles of territory, furnish sufficient data upon which to base the various forecasts, the demand for detailed knowledge of the climate over this great area led to the gradual development of an important and interesting feature of the Bureau's activities. This is the Climatological Service. Under this service, the country is divided into 45 sections, each section covering as a rule a single State, and each having one of the regular observing stations as its section center. Alaska, Hawaii, and the West Indian and Caribbean area each constitute a section. The centers collect every month temperature and precipitation observations from more than 5,000 cooperative and other stations, and publish each a monthly and an annual summary, giving a large amount of climatological data by months and for the year.

Weather and Crop Services

It is essential that farmers, stock raisers, and all others interested in the important problem of supplying the Nation with food keep in close contact with prevailing weather conditions and their effect on farming operations, the growth of crops in different sections of the country, and the condition of the range in the great western grazing areas. To supply this need special weather and crop services are maintained by the bureau, through which such information is made available.

Two services, more or less distinct, are operated, one a daily and the other a weekly.

A large number of special meteorological stations are maintained throughout the principal cotton and grain producing sections, from which daily telegraphic reports of weather conditions are received, and bulletins are published containing this information at 53 central stations in different parts of the country.

The weekly service consists of the publication of a weekly weather and crop bulletin at Washington, covering the entire country. This is released at 10 a. m. each Wednesday. In addition there is published a local weather and crop summary at each State center, containing information in more detail as to conditions prevailing in the respective States. There is also published weekly at New Orleans the Cotton Region Bulletin and weekly at Chicago the Corn and Wheat Region Bulletin. These bulletins are based on information collected each week from a large number of cooperative meteorological observers and weather and crop correspondents covering practically every county in the United States.

In addition a weekly cattle-region bulletin is published at several central points in the western grazing country. Owing to the large expanse of range area some sections may experience severe drought, while others may have ample moisture to supply sufficient food for livestock and some to spare. In such cases it may become necessary to ship stock from unfavorable to more favorable regions, and therefore it is important that weather and range conditions in all parts of the area be known. Again, bankers and others who lend money to livestock raisers require such information. By maintaining these several services the Weather Bureau supplies dependable information at frequent intervals whereby the public is kept informed as to current conditions.

Special Publications

Through the assistance of its several thousand cooperative observers, many of whom have maintained local records for long periods, the Weather Bureau endeavors to collect special local data and thus perfect the records that are needed for the study of the relations between climate and agriculture, forestry, water resources, and other kindred subjects.

In the utilization of these meteorological data the Weather Bureau employs a staff of officials of high scientific ability, who are not only engaged in the practical work already mentioned but are also occupied in the elaboration of those fundamental principles which are necessarily an essential feature in the development of meteorology and its kindred sciences. The results of these investigations are presented to the public through regular and special reports.

Among the publications of the Weather Bureau the following are worthy of special notice:

The annual report of the chief of the bureau, including a full summary of the weather data for the United States for the year.

The Monthly Weather Review, which has been published regularly since January, 1873, contains detailed meteorological tables and charts showing the weather conditions for the month over the United States and neighboring countries, and papers of interest on climatological and meteorological subjects.

Climatological Data for the United States by sections; the monthly summaries for the 42 sections comprising the continental United States, assembled alphabetically by States, into a single volume, with charts of temperature and precipitation, giving for each month very extensive daily climatological statistics for the entire country. Similar climatological summaries are also published for Alaska, Hawaii, and the West Indies and Caribbean Sea region.

A vast amount of climatological data has been prepared in a series of papers each treating of the principal climatic features of a limited area, the complete set, 110 in all. These cover the United States, Alaska, and Hawaii.

There is issued at the central office every Wednesday during the winter a publication entitled "Snow and Ice Bulletin," which shows the area covered by snow, the depth of snow, and the thickness of ice in rivers, etc., as indicated by reports of observations made on the afternoon of the Monday preceding the issue of the bulletin. The publication is of especial value to those interested in the winter-wheat crop, to ice dealers, and to the manufacturers of rubber goods and other articles the sale of which is largely affected by the presence or absence of snow and ice.

The bulletins, published occasionally and now numbering about 70, that contain the larger reports made by the experts of the service.

Library

The library of the Weather Bureau contains about 50,000 books and pamphlets, consisting principally of technical books on meteorology and allied sciences and of published climatological data from all parts of the world. It is available to all Weather Bureau officials and to students of meteorology generally, who either consult it personally or through correspondence. In addition to its

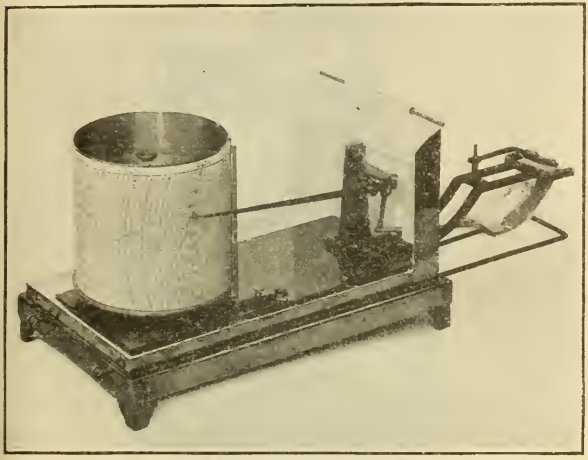

FIGURE 3.—Thermograph

general card catalogue, the library keeps up to date a catalogue of the meteorological contents of the principal scientific serials of the world.

Instruments and Apparatus

The primary functions of the instrument division, which is a part of the central office of the Weather Bureau in Washington, are to select, procure and test instruments and instrumental apparatus for the use of the Weather Bureau in its regular observational program and in special investigations; to design new instruments and to make

improvements in existing ones; to plan exposures of such instruments; to maintain the instrumental and storm-warning-display equipment in the field; and to instruct the personnel of the organization in their use. There is maintained in this division a testing and designing section in which instruments are tested and new models designed; an instrument shop in which first models of new designs

FIGURE 4.—Rain gage

are constructed, and in which, also, many repairs to instruments are made; and a receiving and shipping section in which instruments are prepared for safe shipment.

The United States Government does not manufacture the instruments and apparatus employed in its meteorological work. These, in general, are purchased under annual contracts with manufacturers, from whom instruments and apparatus of the standard Weather Bureau patterns may be procured by private parties. The Weather Bureau will give addresses of manufacturers, when requested, but it can not act as agent in the purchase of instruments, and applicants should correspond and deal

directly with such manufacturers relative to prices and details concerning any articles they may desire.

Persons who wish the errors of a thermometer accurately determined are referred to the director of the National Bureau of Standards, Washington, D. C.,

FIGURE 5.—Making a pilot-balloon observation

who is authorized by law to make official comparisons of this character with the United States standards, for which a small fee is charged.

Forecasts and Warnings

The extent to which the work of the Weather Bureau, in the collection and publication of data and the issue

of weather forecasts and warnings, affects the daily life of the people and becomes a factor in their various vocations and business enterprises, already very great, is increasing yearly.

Storm warnings are displayed at more than 400 points along the Atlantic, Pacific, and Gulf coasts and the shores of the Great Lakes, including every port and harbor of any considerable importance; and so nearly

FIGURE 6.—Plotting a pilot-balloon observation

perfect has this service become that for years few storms of marked danger to maritime interests have occurred for which ample warnings have not been issued from 12 to 24 hours in advance. The reports from the West Indies are especially valuable in this connection, as they enable the bureau to forecast with great accuracy the approach of those destructive hurricanes which, during the period from June to November, are likely to sweep the Gulf and Atlantic coasts. The sailings of the immense number of vessels engaged in our ocean and lake traffic are largely determined by these warnings, and those

displayed for a single hurricane are known to have detained in port on our Atlantic coast vessels valued with their cargoes at over $30,000,000.

The warnings of those sudden and destructive temperature changes known as cold waves are of marked importance. These warnings, which are issued from 24

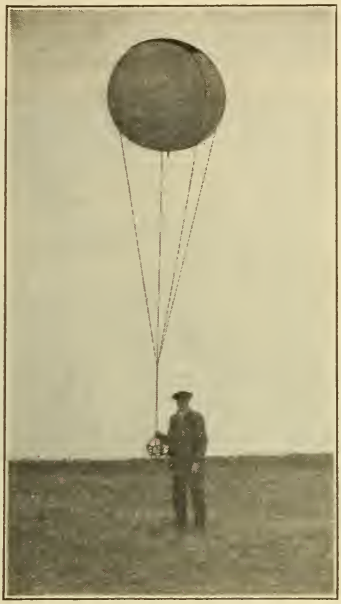

FIGURE 7.—Sounding balloon with meteorograph attached

to 36 hours in advance, are disseminated throughout the threatened regions by means of flags displayed at regular Weather Bureau and subdisplay stations, by telegraph, telephone, radiograph, radiophone, and mail service to all places receiving the daily forecasts, and to a large number of special addresses in addition. The warnings issued for a single cold wave of exceptional severity and extent resulted, as estimated by beneficiaries,

in saving over $3,500,000 through the protection of property from injury or destruction.

The warnings of frosts and freezing weather are also of immense value, particularly to the fruit, sugar, tobacco, cranberry, and market-gardening interests. The early truck-raising industry, so extensively carried on in the regions bordering on the Gulf and south Atlantic coasts and in Florida, and which has increased so greatly in recent years, is largely dependent for its success on the cooperation of the Weather Bureau in this particular, and

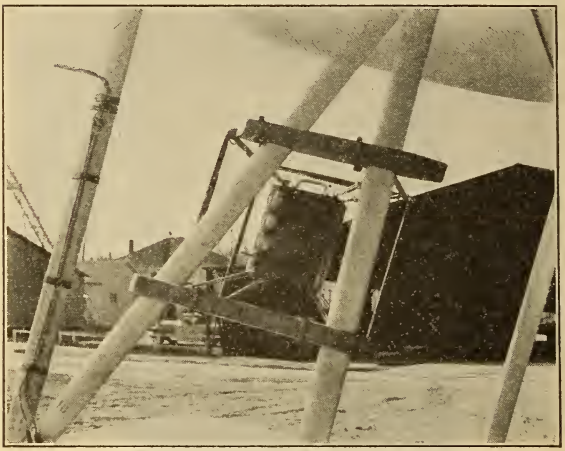

FIGURE 8.—Aerometeorograph mounted on airplane

the growers of oranges and other fruits in Florida and California have received great benefit or escaped losses aggregating many millions of dollars. The value of the orange bloom, vegetables, and strawberries protected and saved on a single night in a limited district in Florida, through the instrumentality of warnings of freezing weather sent out by the bureau, was reported at over $100,000. In the citrus-fruit districts of California it is reported that fruit to the value of $14,000,000 was saved by taking advantage of warnings issued by the bureau during one cold wave.

The deciduous-fruit districts of Washington, Oregon, Idaho, Utah, Colorado, and other sections rely upon the warnings of the bureau to guide them in smudging and heating their orchards on the occurrence of frost or freezing weather during the blossoming period.

Temperature surveys are made in fruit districts in several parts of the country, by which the temperature relations between various sections, differing in susceptibility to frost, are determined, to supply information as to the suitability for fruit growing in relation

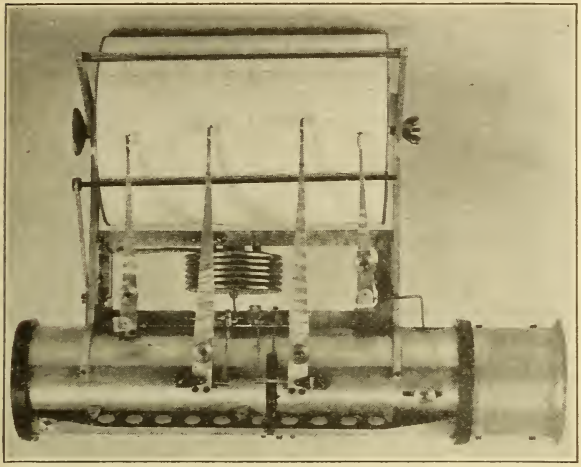

FIGURE 9.—Kite meteorograph showing wind, temperature, pressure, and humidity

to the frost hazard. Numerous substations are maintained in some of the principal fruit areas, especially in the more western States, during the danger period of the year, and trained meteorologists are assigned to assist the fruit growers in protecting their orchards from frost. Considerable experimental work is also done to determine the most efficient and economic methods of protection, for the information of horticultural interests.

While the value of the bureau's reports and warnings to many interests is so obvious as scarcely to need more

than the brief mention already given there are numerous special applications of the information to individual pursuits and industries that may not be realized by the public. An account of some of these may lead to an increased use of the data in quarters where the possibility of their application has not yet been recognized, and additional details of the manner in which the information is utilized in a number of enterprises will doubtless be found of interest.

The railway and transportation companies make continued use of the forecasts in all their shipments. Perishable products are protected against temperature extremes by icing or heating, as conditions may require. Oftentimes shipments of perishable goods are accelerated when it is found possible to carry them to their destination in advance of the expected unfavorable temperature conditions. When this can not be accomplished, goods en route are run into roundhouses for protection. An advance notice of a cold wave will also often hold up a contemplated shipment until after the freeze has passed, and if the cold is protracted the companies will refuse to receive consignments of goods likely to be injured by low temperatures. These precautions apply in some instances to prospective temperature changes within comparatively narrow limits. Bananas, for example, require very careful handling and must be kept at a temperature of 58° to 65° F. during shipment, as a temperature below 55° chills the fruit sufficiently to cause a deterioration in quality, while a temperature above 65° inside the car will produce overripening. As bananas generate heat rapidly after being placed in the car, the problem of maintaining the requisite temperature becomes a delicate one, involving careful ventilation and a study of actual and expected temperature conditions along the entire line of transit.

Similar precautions, based on the information of the daily forecasts and supplemented by a study of the daily weather map, apply to shipments of vegetables, fruits, eggs, and other products liable to damage from extremes of temperature. On the other hand, most meats are best shipped in cold weather, although the use of refrigerator cars prevents loss, and the shipments of live hogs and cattle by freight is avoided, if possible, when a hot wave is expected. High temperatures are also hurtful to certain other shipments, expecially of

fish and oysters, so that the question of the proper amount of ice to be used is intimately connected with the forecasts issued by the bureau. The daily forecasts and the reports of general weather conditions likewise assist in determining the points to which many shipments of perishable articles are directed, in order to meet the irregular demands that are frequently dependent upon the kind of weather that prevails in a given section. The movement of eggs kept in storage, for instance, is largely regulated by temperature changes, the announcement of a cold wave being usually followed by brisker shipments from western supply districts to the eastern markets, in anticipation of a rise in prices.

The uses made of temperature forecasts in the cities are more varied than is generally supposed. With notice of an approaching cold wave greenhouses are closed and boilers fired. Preparations are at once made by heating and lighting plants, whether gas, electric, steam, or hot water, to meet the increased demands that will follow. Fire plugs, exposed mains, and general plumbing are protected. Large stockyards drain their mains. Gasoline engines are drained and automobile water-cooling systems are protected by the use of antifreeze solutions. Work in concrete is stopped. Street-railway companies arrange for more heat in their cars. Natural-gas companies turn a larger amount of gas into their lines to provide for increased consumption. Merchants curtail advertisements or direct attention largely to cold-weather articles. Oyster dealers lay in a larger stock. Coal dealers supply partial orders to all customers needing fuel, instead of full orders to a few, and thus serve all of their patrons. Ice factories reduce their output. The dredging of sand and gravel ceases, and iron ore piled up for shipment is placed in the holds of vessels, to prevent the wet masses from freezing solid. Charity organizations prepare to meet increased demands for food and fuel, and thus minimize suffering among the poor.

The Weather Bureau assists the Forest Service, owners of timber areas, and forestry associations by conducting a project known as the fire-weather warning service. Annual losses from fires in forested areas are enormous. Weather is closely associated with the inception and spread of forest fires. Strong winds, high temperatures, and low humidities create conditions of extreme hazard. The Weather Bureau is of material assistance in protecting the great forests of California, Washington, Oregon,

Montana, and Idaho, and to a lesser extent in Minnesota, Wisconsin, Michigan, the New England States, and the Adirondack and southern Appalachian regions, by furnishing forest-protection agencies with forecasts and warnings of the coming of hazardous weather conditions. Numerous meteorological substations have been established in the forested areas. They are equipped with thermometers, wind-measuring apparatus, rain gages, and other instruments. Reports therefrom are telegraphed to a district center and are utilized in the preparing of fire-weather forecasts and warnings, which are dispatched to forest supervisors and rangers, thus enabling them to make advance arrangements for suppressing any fires which may start. Forecasts of rains also are furnished when large forest fires are under way and are of much value in the conduct of fire-fighting operations. Fire-weather officials especially assigned to this work are engaged in research with a view to extending knowledge of the relation between meteorological conditions and the spread and inception of fires in the forests.

In the agricultural districts the frost and cold-wave warnings are invaluable to the trucker and fruit grower, especially in the spring, when the tender vegetables are protected by covering with paper, cloth, or soil, and fruit is safeguarded by smudging, irrigation, or other methods designed to maintain the temperature above the danger point. In the fall these warnings are utilized in the cranberry regions by flooding the bogs until after the cold weather has passed or danger of frost is over. Many crops, such as beans and grapes, are saved by being picked in advance of the freeze, while tobacco and unmatured corn are cut at once upon advance notice of damaging cold weather. Potato digging is suspended and the dug potatoes removed from the field, and sugarcane is cut and windrowed upon receipt of such advices, immense savings having resulted in the sugar districts of Louisiana as a result of such action. The expected duration and severity of freezes govern operations in the ice harvest. If the cold is to be prolonged, the icemen await the desired thickness, but otherwise the cutting will be hastened in order to secure the best possible returns under the circumstances. Forecasts in spring are helpful in the maple-sugar industry, as the collection and boiling of the sap are more or less dependent upon the coming conditions. The temperature forecasts are also largely utilized by farmers in the killing of hogs, by sheepmen at

lambing and shearing time, and by stockmen in general at critical seasons of the year.

Specialized services are given to fruit growers as an aid to spraying operations and to assist farmers during the harvesting season. They are known as fruit spray and harvest weather services. During certain portions of the blooming and fruiting season the spores of a fungus may, when moistened, infect an apple tree in less than 24 hours unless a poisonous spray is applied just ahead of rains or prolonged moist, misty weather. Forecasts of the character of weather to be expected, as far in advance as conditions shown on the weather map justify, are issued and distributed to orchardists as a guide in spraying operations. Forecasts of a similar character are provided farmers for use in the harvesting of hay, wheat, oats, and other cereal crops. The purpose is to advise them of weather conditions two or three days in advance, in order that they may avoid damage or losses from rains after the crops have been cut and before they can be cured and stored.

Fruit growers are often given valuable service through the supplying of advance warnings of impending cold waves, which enables them to make adequate preparation for fighting frost. Acting on the advice of fruit-frost specialists that an unusually severe frost would likely be experienced in a day or so, which would probably require additional fuel supply, the growers in southern California on Christmas eve and Christmas Day, 1924, to meet the impending emergency, rushed into the orange groves 300 carloads and 175 truckloads of oil, in addition to the full capacity of their regular freight supply. It later proved that if this additional fuel had not been provided, vast quantities of fruit would have been lost. In the Pacific States alone there are some 4,000,000 orchard heaters in use, in the operation of which the growers largely depend on advices and warnings given by the Weather Bureau.

In the raisin-growing districts of California rain forecasts are of great value. The raisin crop while drying is extremely susceptible to injury from rain, and the warnings enable the producers to protect the fruit by stacking and covering the trays. Rain forecasts are also utilized in the large fruit-growing districts to enable picking in advance of rains, so that the fruit can be shipped dry. Vegetables dug in dry weather are also shipped in better condition than those upon which rain has fallen after they have been taken from

the ground. Broomcorn is liable to damage from rain if left in the field. Much saving in alfalfa cutting has resulted from consulting the forecasts, since the alfalfa hay can be baled in the field if dry, but if baled wet will spoil. The same benefits derivable from rain forecasts apply to alfalfa cut for seed, since a heavy fall of rain upon the crop after cutting ruins its commercial value. Rain forecasts are also of much benefit in fruit districts in connection with spraying operations and in other districts during harvesting. Lime, cement, brick, draintile, and sewer-pipe material all require protection from rain during the process of manufacture, and cement work must be protected from rain for 24 to 48 hours after the concrete is laid.

The rain forecasts are used by contractors in their roofing work. Photographic firms working on a large scale find them helpful in planning for panoramic views. City departments determine the number of teams needed in street sprinkling, railroad companies guard against washouts, and irrigation companies control the output of water according to expected conditions of rainfall. Physicians use the forecasts in advice to patients suffering with inflammations of the throat, nose, or ear, where it is expedient that the sufferer should be kept in doors. They are also used by dentists, many of whom make appointments for bright days and reserve their plate work for days with inclement weather. A knowledge of temperature and moisture conditions in advance is of assistance in blast-furnace operations in determining the quality of the output. Warnings of heavy snows are very valuable to railroads by enabling them to organize their snow-fighting equipment and to reduce, if necessary, the tonnage of their freight and passenger trains. They are also necessary on the great western ranches and plains, where the stock is hurried from the ranges to shelter upon notice of blizzards, northers, or heavy snows. Forecasts of bad weather resulting from low temperatures, heavy rains, heavy snows, or a combination of these, are used in regulating advertising, in arranging for automobile or other outdoor trips, in providing for indoor work on the farms, and in guarding school children from exposure to the elements.

Some special uses of the storm warnings are found in the measures adopted to protect property and crops subject to inundation from high tides or backwater blown up by the winds. In advance of a predicted storm, rice planters flood their crops to prevent the straw from being

broken by the winds. Agents of marine-insurance companies refrain from insuring cargoes after a storm has been predicted. Fishermen take steps to protect their boats and nets. Lumbermen make their standing booms secure and regulate their log towing. At lake ports vessels load hurriedly if they can get off 2 to 5 hours in advance of offshore winds; if snow is also expected, a start of 7 to 18 hours is necessary. Considering the cost of operating a vessel, whether standing or moving, a day saved from idleness in the harbor means an appreciable saving in expense.

Among the miscellaneous uses of the various classes of forecasts are their application to the manufacture of certain articles where slight changes in temperature, moisture, and other weather elements have been found to affect the quality of the product. This is true of certain stages in the manufacture of bluing, varnish, oils, cement, lime, bricks, paper, photographic supplies, chocolate candies, and some acids. They also serve usefully the plans of public amusement companies, excursion enterprises, awning companies, and those engaged in outdoor painting.

The daily maps and bulletins and the general bulletins and reports containing statistical data are utilized in many ways by the public. Grain and cotton brokers are guided largely by the forecasts in their operations but need the daily report of current weather conditions as well in their business transactions, while in a less degree the retailer and the small farmer can also use the same information to advantage. Data of atmospheric pressure are used in tests of boilers, radiators, and automobiles, and in studies of the amount of fuel required to drive engines under varying atmospheric pressures. Statistics of wind force and direction assist in the installation of water-supply systems to be operated by windmills, in determining the origin of fires resulting from flying sparks, the pressure to which large buildings will be subjected under stress of heavy storms, and the surface movement of lake waters in connection with the disposal of city sewage. The humidity records are used by silk and candy manufacturers, in tuberculosis investigations, and in studies of the loss of electric current in high-voltage transmission.

Data regarding rainfall and snowfall are extremely useful in planning irrigation enterprises and selecting reservoir sites and are studied in connection with the

construction of waterworks, bridges, culverts, and sewers. River data are utilized by filtration plants in guiding their methods of chemically purifying the water used for drinking purposes, as the conditions of the raw-water supply as regards bacteria content and turbidity are greatly affected by the height of the river and the amount of rainfall. They are also necessary in studies of stream flow, dredging operations, the construction of dams, and in practically every phase of bridge building, levee work, and general river improvement.

The miscellaneous climatological data are used in medical and scientific studies of the relation of weather to diseases and other conditions of health, life, or human pursuits; by railroad companies in the adjustment of claims and demurrage charges; by home seekers; by invalids in search of health resorts; by irrigation investigators; by contractors and builders in settling labor accounts; by merchants in studies of the relation of the weather to their daily sales; by gas and electric light companies in showing their customers the relation of their monthly bills to the varying hours of daylight at different seasons of the year; as adequate testimony in court proceedings; in dry-farming investigations; in studies of soil culture, practical agriculture, and the life and migration of insect pests; in plans for the development of the arid regions; in the preparation of historical records; by bond and investment companies in determining the loan values of farm lands in newly opened sections; in short, in nearly every calling in which the weather plays any part.

Many more uses of the warnings and reports might be cited, but those already given—all of which are taken from personal letters received at the central office of the Weather Bureau or at its field stations—will suffice to show the extent to which they are utilized by the public in the practical everyday affairs of life.

Extension of Forecast Period

Within the last few years the area from which meteorological reports are received daily by telegraph, cable, and radio has been extended to cover practically the entire Northern Hemisphere. By means of the greater survey of atmospheric conditions afforded by these reports it is possible to forecast important weather changes for a week in advance with a fair degree of accuracy.

The Weather Bureau does not attempt to make weather forecasts for longer periods ahead. The subject of long-range forecasting is one that has engaged the attention of its scientists for many years, and thus far no laws of weather sequences have been discovered whereby reliable weather forecasts for long periods in advance can be made. Reputable scientists throughout the world agree that the development of meteorological science, up to the present time, does not admit of the making of forecasts of this character that are at all trustworthy.

River and Flood Service

Human life and large property interests along the rivers of the United States are safeguarded by the issue of flood warnings, the importance of which is emphasized by the disastrous floods in recent years.

The river and flood service is organized with its principal headquarters at the central office of the Weather Bureau, Washington, D. C., and subsidiary district centers at advantageous points on the respective rivers along which a service is maintained. About 66 district centers are maintained outside of Washington.

Measurements of precipitation in the drainage basins of the streams and observations of the height of water on the gages at strategic points are collected by telegraph or telephone from about 900 substations and serve as the basis for warnings of floods. A second useful purpose is served on navigable streams in giving notice of boating stages during the low-water season.

In recent years the operation of the great system of locks and dams on the Ohio River for the benefit of navigation has necessitated a considerable increase in the river and rainfall service of the entire Ohio Basin. Reports are received and river forecasts issued early each morning, and instructions for operation of the dams are based upon these. The dams are operated by the Corps of Engineers, United States Army, whose cordial cooperation has greatly facilitated the work of the Weather Bureau.

Flood warnings are indispensable to all river industries, as well as to the operations carried on in the lands subject to inundation. Their issue is followed by the removal of stock, harvested crops, and other property from bottom lands, and by a general exodus of the inhabitants of the country where overflows endanger human life. Foreknowl-

edge of expected river stages is also of great advantage in determining whether or not it will be advisable to undertake farming operations in the regions subject to overflow. The warnings enable fishermen to remove their fishing gear from the water, so as to avoid damage from driftwood and logs that are brought downstream by the rise, and to devote their energies to gathering this drift for sale.

Along the river streets of many cities the basements of warehouses and other buildings are submerged at high water. Accurate river forecasts are a guide to business men in moving their goods to upper floors and often prevent the needless expense of such a transfer in cases where it is known that the flood crest will be below the point at which their stocks in basement and on ground floors would be imperiled. The warnings enable dealers to save wood and ties piled along the river banks. Navigation companies utilize river forecasts in arranging for the transfer of their offices and landing places from lower to upper docks. A knowledge of slight rises is often of great value, as these frequently permit large freight movements by water. Lumbermen cut much timber in the swamps and along the streams during low water, looking to the rises to carry out their logs; advance information of coming stages enables them to have everything in readiness to prosecute their work without loss of time when the favorable conditions arise. During rising water those in charge of locks, dams, and levees are alert to the need of strengthening and protecting the property under their care; exact forecasting guides their operations as to time, place, and amount of protection, or may save them from expending money and effort in protective measures that will not be required.

Fishermen in the Columbia River district claim that the water stage has an effect on the entrance of salmon from the ocean, and that by watching the river forecasts a spurt in the run of fish can be predicted with a fair degree of accuracy. Forecasts of low-river stages are of great value to many interests. When the stage falls below a given height many water-power plants have their supply cut off; with ample notice, they can have their auxiliary steam plants ready for use and thus continue their business without interruption. Pile driving, dredging, and repairing are largely done during low-water stages, previous notice of which enables engineers to arrange for such operations.

Aerological Observations

The "upper atmosphere" to which aerological observations refer is generally recognized as that portion that is out of range of surface recording instruments and usually applies to heights above 50 to 100 feet. A knowledge of upper-air conditions is becoming increasingly important both for purposes of general weather forecasting and for furnishing the necessary data to aviators.

Upper-air observations are made by the Weather Bureau by means of pilot balloons, ceiling balloons, sounding balloons, limited-height sounding balloons, airplanes, kites, and captive balloons. The two latter methods, however, are rapidly being replaced by airplanes because of the danger of the kite and balloon wire to aircraft. Each of the methods mentioned has its own particular advantages and shortcomings; when all are used, they supplement one another very satisfactorily.

Pilot balloons indicate the wind direction and velocity at various elevations. Rubber balloons, 6 inches in diameter, are inflated with hydrogen gas to approximately 28 inches in diameter, and after their release are followed by means of a theodolite. (Fig. 5.) From the elevation and azimuth angles as read each minute and the known height of the balloon (the ascensional rate being uniform for a definite "lift" of hydrogen) the wind directions and velocities are readily computed. Pilot-balloon observations occasionally extend to heights of 6 to 9 miles. They are made at night by attaching a small paper lantern containing a lighted candle or a small electric light to the balloon. The light is then followed instead of the balloon. Night observations seldom extend to heights over 2 miles.

Ceiling balloons are used to determine the height of clouds when the latter cover the entire sky and are relatively low—i. e., 2,000 feet or less. They are smaller than pilot balloons and, rising at a known rate, are followed by the eye and timed until they enter the cloud base. At night these heights are determined by means of a ceiling light, which is set at a definite angle and which projects a spot of light on the cloud base. By means of a climometer the angular height of the light spot is obtained and the cloud height determined.

Sounding balloons are usually 5 feet or more in diameter and carry a self-recording instrument (meteorograph). (Fig. 7.) The balloon rises until it bursts, and the meteorograph then descends with a parachute. Continuous

records of temperature, pressure, and humidity are thus obtained to heights of 10 to 12 miles and occasionally to 20 miles. The instrument carries a tag on which the finder is requested to send it to the Weather Bureau office, for which service a payment of a few dollars is made. The percentage of returned instruments in this country is usually between 80 and 90. The majority of the instruments land within 50 miles of the station and many land at less than half that distance. The chief disadvantage of sounding balloons is that the records are frequently not available until days, weeks, or perhaps months later.

Limited-height sounding balloons are similar to sounding balloons except that a deflation device is used which limits the height reached and therefore the distance away at which the balloon falls. This method is especially suitable in sparsely settled regions or over water areas, where the chances of having the instrument found are remote.

Airplanes provide a very suitable means of upper-air observations. A meteorograph can thus be carried to heights of 3 to 4 miles, and very satisfactory records of temperature, pressure, and humidity can be obtained in a comparatively short time.

Airplane observations have been made regularly at several stations by the Navy Department for several years. The observations at the Naval Air Station, Anacostia, D. C., are made in close cooperation with the Weather Bureau. This method of upper-air observation has proved so satisfactory that the Weather Bureau is now (1931) arranging with air-transport companies at a number of places throughout the country to make daily flights to heights of 13,000 feet or more. The Weather Bureau will furnish the aerometeorographs (fig. 8) and also the personnel to place the instrument on, and remove it from, the airplane for these observations. These records will be promptly computed and telegraphed to the district forecast centers, where they will be used in the regular forecast work of the bureau.

Kites (box type) are flown in tandem from steel music wire. The head kite carries a meteorograph (fig. 9) and by using from six to eight kites, heights of 2 miles and occasionally 4 miles are reached. The chief disadvantages of kites are: (1) The relatively long time required (from four to five hours) to make a flight; (2) the necessary wind and weather conditions; and (3) the danger of the wire to aircraft and when breakaways occur.

Captive balloons are used to supplement kites when winds are light. (Fig. 10.) The heights reached are less than those with kites, and the danger of the wire must also be considered.

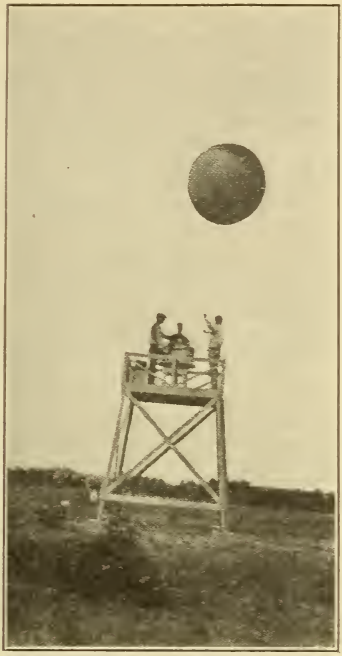

FIGURE 10.—Making observation with captive balloon, showing platform and reel

Since the passage of the air commerce act of 1926 the Weather Bureau has organized a very intensive weather service for aviation in the United States, Alaska, and Hawaii. At the beginning of 1931 there were about 57 Weather Bureau pilot-balloon stations in the United States, 2 in Alaska, and 1 in Porto Rico. From two to

four balloon observations are made daily at these stations. Airport stations, established primarily for airways service, are in operation at about 53 places with commissioned personnel, and in most cases 24-hour service is maintained.

In addition there have been established about 325 airways stations having noncommissioned personnel. At many of the latter 24-hour service is provided, whereas at others only the necessary service for scheduled flying is maintained. The service at those places includes frequent reports of current conditions, both surface and upper air.

Transmission of airways reports is under the jurisdiction of the Department of Commerce and is made by leased "teletype" lines. The reports include the general conditions of sky and weather; ceiling; visibility; surface-wind direction and velocity; temperature; barometric pressure; and miscellaneous conditions such as thunderstorms, squalls, and state of landing fields as affected by rain, snow, etc. Upper-air conditions and dew-point temperature are included when available.

Certain airport stations have been designated airways forecast centers. To these stations 3-hour reports are sent from a number of surrounding stations, weather maps constructed, and short range forecasts issued. The airways reports, forecasts, and summaries are broadcast regularly and frequently from Department of Commerce stations located along the airways. These broadcasts not only provide valuable data to flyers but are available to anyone having a suitable radio receiver.

All upper-air observations are sent to the central office of the Weather Bureau at Washington and the records are summarized and studied in connection with special investigations. Monographs containing the results of these studies are published as supplements of the Monthly Weather Review, or as bulletins of the National Advisory Committee for Aeronautics, and the National Research Council, and shorter papers in the Monthly Weather Review.

Solar Radiation

This research has for its object the measurement of the solar thermal energy received at the surface of the earth, the brightness of the sky, and the intensity of daylight, at different seasons of the year and under different atmospheric conditions. It includes measurements of the dust

content of the atmosphere, a study of the influence of this dust upon thermal and luminous solar radiation intensities, and the improvement and standardization of apparatus employed in radiation measurements. Such apparatus is now installed at seven Weather Bureau stations, and through cooperation with other bureaus and with universities measurements obtained at four other stations are received. All these radiation data are summarized for publication in the Monthly Weather Review.

Solar-radiation data are not only in demand for general climatological studies, but also for biological studies. The Weather Bureau is also represented on an international commission that is studying the relation between solar-radiation intensity and atmospheric circulation, upon which weather conditions depend.

Employees

The conduct of the regular stations of observation outside of Washington requires the constant services of more than 1,000 employees, and the business of the central office at Washington of about 250 employees. The annual disbursements of the bureau amount to about $4,500,000.

Appointments to the positions in the Weather Bureau are made only after examination and upon certification by the United States Civil Service Commission. Original appointments are, as a rule, to the lowest grades. Applicants for positions should communicate directly with the United States Civil Service Commission, Washington, D. C., relative to the regulations governing examinations and the time and place of holding them.

The numerous offices of the bureau throughout the country are always open during business hours, and the public is cordially invited to visit them and avail itself of the information contained in the records there on file.

For the Benefit of All

The Weather Bureau is maintained and conducted in the interest of all the people, and the chief of the bureau earnestly desires that the greatest possible use be made of the very large amount of meteorological data accumulated during the 60 years of its existence, and that the widest possible distribution be given to the daily weather fore-

cast and warnings issued. Information as to how the data and publications of the bureau may be obtained and the steps necessary to secure the receipt of forecasts

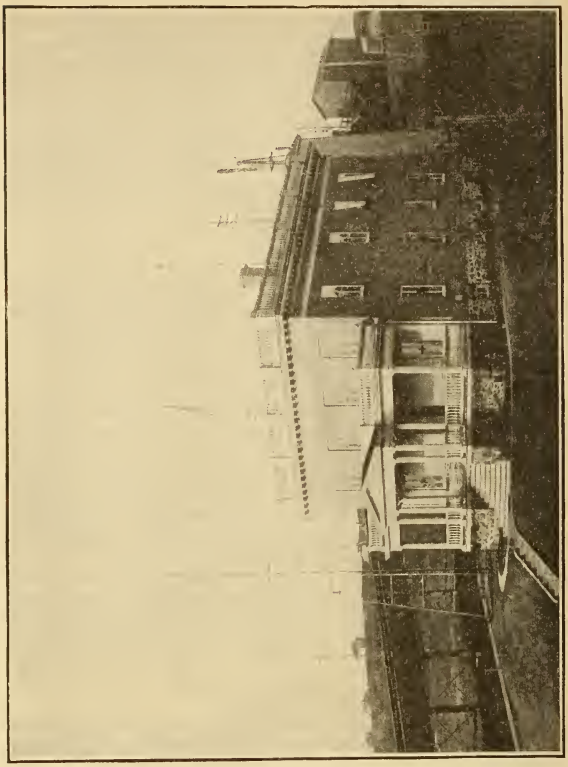

FIGURE 11.—A Weather Bureau observatory

and warnings will be promptly furnished on request. Communications should be addressed to the Chief, United States Weather Bureau, Washington, D. C.

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